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Late Pleistocene Incision Rate Patterns Confirm Long-term Differential Uplift of the Western Syntaxis of the Himalaya along the Indus River in Northern Pakistan

J F Leland and M R Reid (Dept. of E&SS, University of California, Los Angeles, CA 90095; 310-825-3880; leland@.ess.ucla.edu)
D W Burbank (Dept. of Geological Sciences, University of Southern California, Los Angeles, CA 90089; 213-740-6099)
R C Finkel and M Caffee (LLNL, Livermore, CA 94550; 510-423-8395)

Well-preserved, river-cut bedrock surfaces (straths) abandoned by progressive incision of the Indus River in northern Pakistan have been dated using *in situ* cosmogenic ^{10}Be and ^{26}Al exposure age dating. Strath exposure ages range from 0 age for actively forming straths to 65 ka for straths 150 m above the river. The data show that straths form quickly with essentially no buildup of cosmogenic nuclides prior to strath abandonment. The results also show that higher straths yield older exposure ages than lower straths as expected.

The pattern of strath exposure ages shows two striking features: 1) the exposure ages of straths at similar heights above the river decrease downstream toward the active Raikot fault zone bounding the western syntaxis of the Himalaya; and 2) the exposure ages of the low straths < 80 m above the river are unusually young when compared to the high straths > 145 m above the river. The downstream decrease in exposure ages can be interpreted as a downstream increase in incision rates in both the high and low straths. Incision rates calculated from the low straths show that incision rates nearly tripled throughout the study area between 7 and 18 ka. Despite the dramatic increase in incision rates between the high and low straths, the difference in incision rates between the upstream and downstream portion of the study area is consistently 2.3 m/ka and likely represents the maximum rate at which the downstream portion of the Indus within the western Himalayan syntaxis is uplifting relative to the upper reaches. The near tripling of incision rates throughout the study area between 7 and 18 ka is likely related to a climatically induced increase in discharge during that time period. The lack of change in the differential incision rate over the last 65 ka shows that short-lived increases in discharge in this system do not change longer-term patterns of incision governed by tectonics.

A model that holds the gradient of the Indus as a constant through time best describes the pattern of strath exposure ages and incision rates and requires downstream uplift of the Indus' channel. A comparison of exhumation rates calculated from Zeitler's (1985) apatite fission track ages and the maximum differential uplift rate calculated from the incision rates suggests that the geotherm in the area is likely to be steep. Interestingly, areas with highest relief correspond to areas where incision rates appear to exceed exhumation rates. This observation supports the conclusion that hillslope denudation is ultimately controlled by rock strength in this area.

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3. (a) John Leland
Dept. Earth & Space Sciences
UCLA
Los Angeles, CA
90095

(b) 310 825 3241

(c) 310 825 2779

(d) leland@.ess.ucla.edu

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5. (a) T05: Structure and Evolution of the Tibetan Plateau
(b) 8107 Continental neotectonics
9320 Asia
1035 Geochronology

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